Friction as a Tool for Winter Maintenance

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Keeping roads clear of snow and ice during the winter season requires a considerable expenditure of resources. Studies suggest that upwards of $2 Billion is spent on direct winter maintenance activities annually, and indirect costs could be a factor of ten greater. Accordingly, it is important that winter maintenance activities be conducted as efficiently as possible. An important step toward efficiency is the development of quantitative measures of the state of the road surface. Such measures would allow determination of the level of activity required to bring the road surface to a safe condition. One such measure is road surface temperature. Measurements of road surface temperatures have been conducted for at least twenty years by means of Road Weather Information Systems (RWIS). More recently, truck mounted sensors have been tested to determine their effectiveness. While these must still be considered experimental, their use has been enthusiastically greeted by some winter maintenance personnel, as providing real time on-the-spot information that can be of considerable use to operators. Unfortunately, temperature alone does not tell the whole story of the condition of a road surface. A key component is the road surface friction. However, before friction measurements can be used as an objective, quantitative measure of road surface condition, a number of issues have to be addressed. The purpose of this paper is to raise and address some of these critical issues.

INTRODUCTION

Winter weather poses a significant hazard to road transportation for many parts of the United States. Keeping roads clear of snow and ice is a significant challenge that has been estimated to cost more than $2 Billion per year. While this cost is significant, the service provided is critical from several aspects (*1*). Roads must be cleared of ice and snow rapidly and efficiently both to provide a safe road surface for the driving public, and to ensure timely delivery of goods that are carried by road. This latter point is growing in importance as "just-in-time" business practice becomes the norm (*2*).

Indeed, far from a desire to reduce levels of service to obtain savings, the trend in recent years from road users has been to demand higher levels of service. Thus any reductions in maintenance costs must come from more efficient operations. One way in which such savings might be obtained is through using new technology to allow maintenance crews to "work smarter." A number of new technologies have grown in prominence in the U.S. winter maintenance community since the Strategic Highway Research Program was conducted, including anti-icing, RWIS, and improved snow fence design. Other new technologies are being considered but are not yet in operational use. One such technology is the use of friction measuring devices as a real time measure of road surface condition.

Friction measuring devices have been used for a number of years to measure the conditions of pavements under wet and dry conditions. There are a variety of different devices, and the readings given by these devices can be related by means of the PIARC standard curve (*3*). However, no such standard exists for friction devices used on snow or ice covered pavements. Indeed, there are relatively few data available to indicate what friction levels cause problems for drivers under winter conditions, and how friction levels change as a storm progresses, and as the road is subsequently treated. Obviously such information must be developed prior to friction measuring devices can be used operationally. However, discussion of such research uses of friction measuring devices is beyond the scope of this paper (though see [*4*], for a discussion of some of these issues).

The purpose of this paper is to consider how friction measuring devices might be used operationally, and to define the conditions under which such use would be beneficial. The paper will first consider how the devices might be used, and will then discuss means by which the costs and benefits of these techniques can be assessed.

OPERATIONAL USES OF FRICTION MEASURING DEVICES

In order to be an effective tool for winter maintenance activities, a friction measuring device must provide information that allows decisions about winter maintenance activities to be made. This means that such tools must bring about a change in how winter maintenance is currently performed. If such a change does not occur then the tool cannot bring any new benefits to the process of winter maintenance. This is an important factor in determining how effective friction devices can be.

Since friction devices are not in full operational deployment at present in any winter maintenance operation at any location worldwide, it is difficult to say exactly how friction measuring devices will be used. However, present discussions seem to indicate they will be used in one of three ways: As a measure of quality; as a source of road user information; and as a means of controlling chemical application.

Friction Devices As A Measure Of Quality

The first envisaged use of friction measuring devices would be to measure road surface friction as a measure of quality. Friction devices would be mounted on a few vehicles (for example, supervisors' trucks). This usage may become especially prevalent in Finland (Anttalainen, *Personal Communication*, 1998) as a method of

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ensuring that contractors have performed an adequate job of winter maintenance over a given stretch of highway. This has the benefit of providing a direct and immediate measure of road surface condition, that can then be compared with desired conditions, and appropriate action taken if required standards are not met.

For this sort of deployment, direct measurement of savings will be hard to obtain, but a consistent standard of quality will be attained with such devices. Additionally, no other method of measuring quality of service seems likely (at this time) to offer such a consistent and repeatable measure. However, it should be noted that at present there is little knowledge about the relationship between friction levels and safe driving conditions (*4*). For this usage to become effective, considerable research is required to link road friction measurements with perceived and actual road conditions.

Friction Devices As A Source Of Road User Information

The second potential use of friction devices is as a means to provide information and/or warnings to road users about road sections in which friction is particularly low. This use could be achieved by mounting friction measuring devices on a few trucks within a fleet, and having these trucks continuously monitoring the road network for areas of low friction. If such areas are found, the information can be relayed (probably by automatic, electronic means) to a central location, from which appropriate warnings can be issued. The warnings may be issued through variable message signs, or via a graphical representation of the road system (perhaps on the web or at rest areas). Most likely, the information would be included with issued weather information from RWIS sites.

One concern with this use of friction devices is ensuring the timeliness of the information. Typically trucks take three to four hours (or more) to make one circuit of a route. Thus, if all roads within an area were to be covered then information would be up to four hours old, if all trucks were equipped with the measuring devices. If only a few trucks or supervisors vehicles have the devices, then data may be even more dated. Most likely, such a usage would be confined to limited sections of road, for which low friction is perceived as a major problem.

Again, for this type of device usage, direct analysis of benefits and costs is difficult to perform. This form of usage results in no direct savings, and considerable additional costs (extra vehicles out during a storm, and new equipment needed for those vehicles, along with other infrastructure such as variable message signs). There may however be significant indirect savings especially in regard to reduced accidents. Use of such a system would require that sites be chosen for which accident rates in low friction conditions are high. It should be stressed that at present no such systems are envisaged for deployment, and while all the parts necessary to make such a system work exist, the concept has not been tested. Such field testing is clearly necessary before a full analysis of benefits can be made.

Friction Devices As A Means Of Controlling Chemical Application

The third potential use of friction devices is as a controlling input for chemical delivery systems on board snow plows. In essence, the friction device would measure the road surface friction and based on the value found (and other inputs) would determine how much de-icing chemical should be applied to the road surface to bring about a suitable friction level in a desired time frame.

Preliminary measurements of friction on the road surface under winter conditions (e.g. [*5*]) indicate that friction can vary considerably over short distances. In one run that they present, measured under conditions of slush and wet pavement, friction values ranged between 0.9 as a high and below 0.2 as a low, over a distance of 20 km (12.5 miles). This variability may well be due to variable road conditions, and highlights the possible usefulness of such information. The authors suggest that the use of friction limits to determine salt application could limit the quantity of salt applied. In this case, using their suggested standard (heavy salt for values below 0.4, light salt for values below 0.6 and above 0.4) heavy salting would have been required for 8 km, light salting for a further 6 km, and no salting for 6 km (note: these are calculated from [*5*], by the author of this study. The authors of [*5*] did not report such calculations). Current practice would require the whole 20 km segment to receive heavy salting. Assuming heavy salting to be 110 kg/lane kilometer (400 lb/lane mile), and light salting to be 55 kg/lane kilometer (200 lb/lane mile), a saving of about 990 kg of salt (for each lane) would have resulted from the current standard of 2200 kg per lane through the segment. This represents a 45% reduction in salt use, which is a considerable saving. However, it is not clear that such high levels of savings would always be attainable. Nor, as the authors note, are the levels of friction for different chemical treatments based on any valid data - they are merely suggested as seeming suitable by the authors.

Nonetheless, such preliminary studies indicate what might well be the most promising use of such devices. Reducing salt usage is of benefit not only for reducing cost, but also for reducing damage to pavement (due to corrosion of re-bar and subsequent spalling of concrete). However, for such an approach to be maximally effective, it would have eventually to be applied fleet wide, rather than to just one or two trucks. Further, there is considerable work required to determine what friction levels require what amount of salt under which conditions. Finally, the usefulness of such an approach is limited (but not totally negated) if an anti-icing rather than de-icing approach is used.

As indicated above, the value of such uses of friction devices is hard to quantify at present, because such devices are not yet fully deployed. Nonetheless, a simplified cost benefit analysis may be performed that gives a preliminary indication of what such devices should cost to break even. Such a first level analysis is presented below.

PRELIMINARY COST BENEFIT ANALYSIS

A simple cost benefit analysis of the use of friction devices to control chemical applications is given in this section, but it should be noted that this analysis makes a number of assumptions that are not currently justifiable. These assumptions are identified explicitly in the following:

Assume that the use of friction devices results in a reduction in the use of chemical de-icers of R%. This reduction is from a base level of de-icer usage (i.e. the amount of de-icer used now, without friction devices) of D tons per year, at a cost of $C per ton. Thus

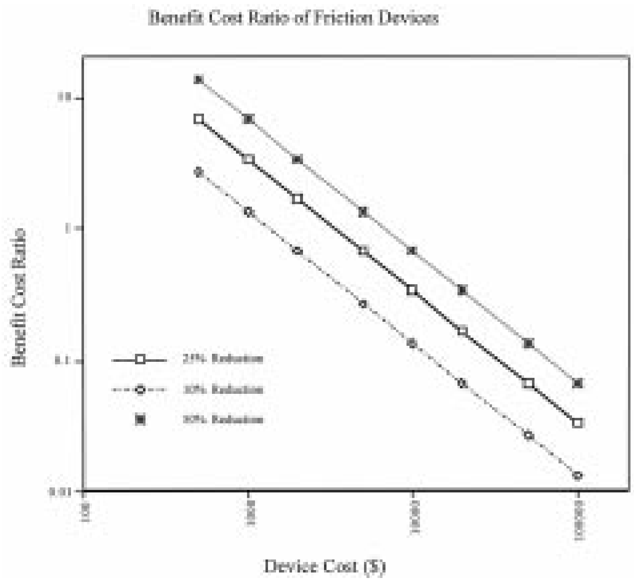

FIGURE 1 Benefit-cost analysis for friction devices.

the potential savings of friction devices ($S per year) can be expressed as:

$$S=(\frac{R}{100})DC$$

Thus if 70,000 tons of salt per year are used now, at a cost of $25 per ton, and a full fleet of friction devices in use results in a reduction of salt usage of 25%, then annual savings are $437,500. Note that the assumption of a reduction in salt usage of 25% is *highly* speculative. However, this represents the direct material benefits of using friction devices. There may also be labor cost savings, and there will likely be indirect savings, due to less salt damage of the pavement, and fewer accidents and delays (because of a higher level of service). At present, these additional savings are not considered.

Of course, the friction devices come with a cost. If each device costs $M to purchase and install, and there are F vehicles in the fleet, then the total cost of installing devices in the fleet ($P) is given simply as $MF. Typically, however, such costs are annualized over the lifetime (n years) of the device, by assuming a percentage cost of money of i% per year. This is a standard equation from economic analysis, and it gives the annual cost ($A) as:

$$A=P\left(\frac{i(1+i)^n}{(1+i)^n-1}\right)$$

Thus, if a ten year life is assumed for the equipment, with a percentage cost of money of 5%, a fleet size of 1,000 vehicles and a device cost of $1,000 per device, the annualized cost (A) is $129,500. The benefit-cost ratio (B) of the installation is then calculated as:

$$B=\frac{S}{A}$$

The worked example above gives a ratio of 3.38. That is, every dollar spent on friction devices would result in somewhat more than three dollars in savings. However, note that costs assumed a unit cost of $1,000 per device installed, a very low figure given current costs, and that no account was taken of training costs for use of the new equipment. Nonetheless, the example does show a simple methodology for considering the benefits of such a system. It also indicates the sensitivity of such analyses to a variety of different factors.

This sensitivity is made more explicit in Figure 1. This shows the benefit-cost ratio as a function of the initial device cost for three different levels of salt reduction (10%, 25% and 50%). The plot is linear in log-log space, and shows that if a 25% reduction in salt usage is achieved, then break-even (a benefit-cost ratio of one) requires an initial cost of around $3,400. As indicated above, there are many assumptions in this analysis, and before any great faith can be placed in such an analysis, considerable research is required to clarify some of the assumptions.

CONCLUSIONS

The following conclusions can be drawn from this study.

1. Friction devices are being considered for at least three different modes of use in winter maintenance: as a measure of quality, as a source of road user information, and as a means of controlling chemical application.
2. All three of these uses are not yet operational, and considerable information is required before their success or otherwise in such uses can be evaluated.
3. A preliminary cost benefit analysis for friction devices as controls for chemical application has been conducted, but too much uncertainty exists at present with regard to potential savings for the results to be of any more than academic interest. Nonetheless, a methodology for conducting such studies in the light of better data has been established.

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REFERENCES

1. Nixon, W. A. and N. S. J. Foster. *Strategies for Winter Highway Maintenance,* University of Iowa Public Policy Center Report, 1996.
2. Forkenbrock, D. J., Foster, N. S. J., and M. C. Krum, M. C. *Transportation and Iowa's Economic Future.* Report prepared for the U. S. De-

partment of Transportation, Iowa Business Council, and Iowa Department of Transportation. University of Iowa Public Policy Center, Iowa City, Iowa, 1993.

3. World Road Association. *International PIARC Experiment to Compare and Harmonize Texture and Skid Resistance Measurements, AIPCR - 01.04.T,* PIARC technical Committee on Surface Characteristics C1, 1995.
4. Nixon, W. A. *The Potential of Friction as a Tool for Winter Maintenance: Iowa Department of Transportation Project TR 400,* IIHR Technical Report # 392, 1998.
5. Fleege, E. J., Wambold, J. C., and Z. Rado. *Variable Slip Friction Measurement Techniques for Snow and Ice Operations, Paper E-10,* 4th International Symposium on Snow Removal and Ice Control Technology, Reno, Nevada, 1996.